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# AN OBSERVATION OF MESOSPHERIC (NOCTILUCENT) CLOUDS FROM SPACE

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ABSTRACT: The authors point out numerous advantages to investigating noctilucent clouds from an orbiting spaceship rather than from ground-based stations. They discuss the geometrical relationships involved in such observations and their effect on the observations. The observation on June 9, 1970 by cosmonaut V. I. Sevast'yanov from "Soyuz-9" of features at an altitude of ~80 km in the Earth's atmosphere may have been of noctilucent clouds, although as the authors point out, they exhibited details of a somewhat different type from noctilucent clouds observed from ground-based stations. Unfortunately, Sevast'yanov's photographs of the clouds he observed were underexposed.

## INTRODUCTION

As is well known, mesospheric (noctilucent) clouds are formed near the /1066* mesopause at an altitude of 80-85 km above the Earth's surface [1, 2]. They are observed from the Earth's surface in the narrow latitude zone from 45 to 70° only in the summer hemisphere in the Earth and only at twilight when the Sun is at angles of 4 to 16° below the horizon. Starting from 1957, mesospheric clouds have been regularly observed by the network of the U.S.S.R. hydrometeorological service and also by stations of a number of foreign countries (Canada, U.S.A., England, Sweden, Federal Republic of Germany, and others); such observations are of great significance for an understanding of many processes which take place near the mesopause. Tropospheric cloudiness severely hinders observations of mesospheric clouds from the Earth's surface. The mesospheric clouds can be observed in practice only in the case of a clear sky in the direction of the sunset segment. Therefore all observations which are carried out by ground-based stations are fragmentary and incomplete.

Notwithstanding their apparent high surface brightness, mesospheric clouds have a very low spatial particle concentration (of the order of 1 particle per

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* Numbers in the margin indicate foreign pagination.

10 $cm^3$). As a result of this situation and also because of the forward scattering of light by mesospheric clouds, the latter are observed as a rule only at small scattering angles of 10-30°, i.e., low above the horizon. Such a position on the celestial sphere makes photometric and spectral observations from ground-based stations very laborious and of low accuracy because of the great weakening of the light both along the ray's path from the clouds to the observer and also along its path prior to incidence on the cloud particle.

Investigations of mesospheric clouds from outer space would evidently not have the indicated inadequacies of ground-based observations; however, until recently not a single case of their detection from on board a spacecraft (SC) has been noted. Only in 1964 at the time of the flight of "Voskhod" did K. P. Feoktistov observe the illumination of atmospheric layers at altitudes of the order of 80 km [3].

How would mesospheric clouds look if they were observed from a space orbit, and what are the conditions under which they would be visible?

The geometrical arrangement of an observation of mesospheric clouds from a ground-based station and from space is illustrated in Figure 1. If mesospheric clouds *M* can be observed from the ground-based stations *E* only from below, then they can be seen from the spacecraft's orbit not only from below from the point *C* but also from above from the point *A* and edge-on from the point *B*; if the spacecraft moves in the direction *A-B-C*, the mesospheric clouds will first rise above the edge of the Earth's surface, reach a maximum height when the spacecraft is at point *B*, and then descend to the horizon, redden, and disappear, not reaching the edge of the Earth's surface because of the extreme weakening along the ray's path from the cloud to the observer. It is not difficult to calculate that the maximum distance of mesospheric clouds from the Earth's edge is an angle of the order of 3°.

In the case of observations from the Earth's surface, mesospheric clouds are at a distance of the order of 500 km from the observer. When they are observed from space, for example at the point *B*, they are located at a distance of about 1500 km from the observer. Thus when mesospheric clouds are observed from on board a spacecraft, they will occupy a smaller area on celestial /1067

spheres (the length of the field is about 20-40°) and their details will have significantly less angular size.

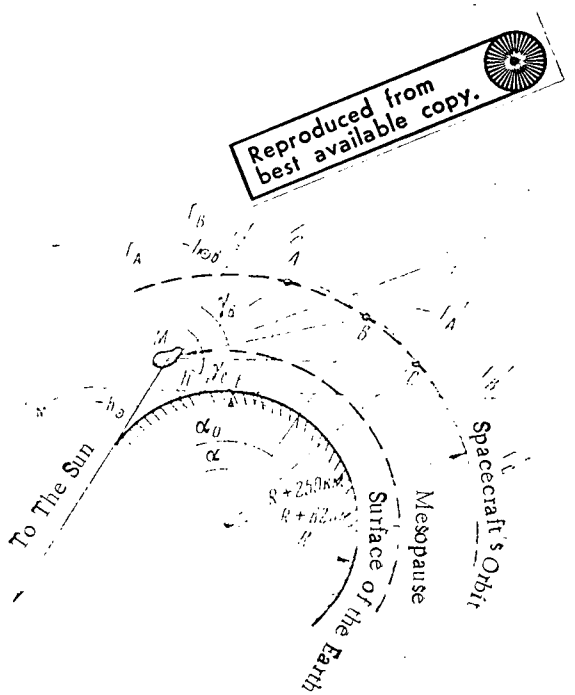





Figure 1. Geometrical Arrangement of an Observation of Mesospheric Clouds. *M* denotes the mesospheric clouds; *E* the ground-based observation station; *A, B, C,* denotes successive positions of a spacecraft during its motion along its orbit; 1 is the horizon of the ground-based station; 2 are the horizon of the spacecraft at positions *A, B, C,* respectively; 3 is the horizon of the mesostheric clouds; 4 is the angular distance of the Sun below the horizon in the case of an observation from the ground-based station and the spacecraft (with subscript *A, B, C,*); 5 is the height of the mesospheric clouds above the horizon in the case of an observation from the ground-based station; 6 is the scattering angle of light for the case of an observation of mesospheric clouds at the time of observation from the ground-based stations (without subscript) and the spacecraft (with subscript *A, B, C,*); R is Earth's radius and 7 is the distance from the noctilucent clouds to the observation station (without subscript) and the spacecraft at positions *A, B, C.*

The sub-satellite point on the Earth's surface when the spacecraft is at position *B* is situated at 7.5° less in longitude than the corresponding ground-based station (when the spacecraft is at position *C* this angle is still larger). Therefore mesospheric clouds can evidently be observed from a space orbit and at lower latitudes than from ground-based stations, possibly down to latitudes of 30°. The Sun's angle of depression below the horizon for the sub-satellite point will also vary within wider limits, also possibly down to 30°

Concerning the surface brightness of the mesospheric clouds and their contrast with the background, the estimates which have been carried out show that under the most suitable conditions their surface brightness and contrast with the background should be higher in the case of observations from space than for observations from the Earth's surface [4, 5].

On June 9, 1970 during the flight of the "Soyuz-9" spacecraft, features in the Earth's atmosphere very similar to mesospheric clouds were first observed by the cosmonaut on board Flight-Engineer V. I. Sevast'yanov on the 117th revolution of the flight, "Soyuz-9" was situated in the summer hemisphere of the Earth over the territory of the Arabian Peninsula ($\phi$ = 33-25° N. Lat., $\lambda$ = 38-45° E. Long.). At $2^h56^m34^s$ Moscow time, "Soyuz-9" crossed the terminator and was over the Earth's nighttime side. At $3^h05^m00^s$ bright luminous bands of zig-zag shape were noticed in the direction of azimuth 10-15° from the solar vertical. A skematic illustration of the observed picture is given in Figure 2, which represents a photograph of a drawing made by V. I. Sevast'yanov in his on board notebook. The observed features were white in color and similar to the bright reflection which results when light is reflected from a polished metal surface or to the solar highlight seen upon observation of a river on the Earth's surface from the orbit of a spaceship. These features had an extended flat filamentary-cellular structure parallel to the Earth's surface. As the spacecraft moved along its orbit, they first rose above the edge of the Earth's surface and then descended. The observer received the impression that they were rotating around a horizontal axis.

The features had their maximum development at $3^h06^m58^s$, when their maximum brightness and largest flatness was observed. Their angular distance from the Earth's edge was ~3° at this instant. Descending to the Earth's edge, the features acquired a redish coloration, and their brightness weakened. At $3^h07^m30^s$ they ceased to be visible, not having reached the edge of the Earth's surface.

V. I. Sevast'yanov took photographs of the sections of the sky where the zig-zag-like bands were observed. Unfortunately, these features were not visible on the photographs because of underexposure.

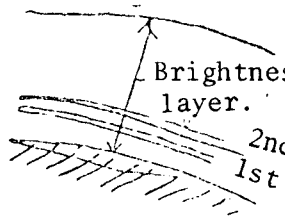
Observation of sunrise on the 117th revolution.

Entry into the shadow $02^h56^m34^s$.

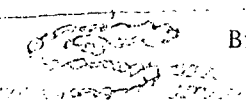
Middle of the Shadow $03^h06^m58^s$.

Exit from shadow $03^h06^m21^s$.

To scale.




To Scale.




I observed an interesting phenomenon. $03^h07^m50^s$. No more traces of this phenomenon, the layer was clean. Probably we were resting.

I observed sunrise at $03^h20^m00^s$. The entire layer increases in brightness, lightens and at the instant of appearance of the first rays of the Sun loses its role to the 2nd brightness layer. The 1st and 2nd layers appear sharper than the boundary of the impending sunrise.

$03^h22^m00^s$. Formation (altitude of the Sun, 6°.6 of "whiskers" Both at once. [Remainder illegible. Gist is the 2 whiskers disappear at $03^h30^m00^s$ when the Sun's altitude is 50°.8.]

More similar to the confused [Illegible Word], from an airplane, but very [Illegible Word] brightness like solar highlight from a river.

I think that those were noctilucent clouds.

Figure 2. Photograph of a Drawing in V. I. Sevast'yanov's on Board Notebook of the Observed Phenomenon.

If the features observed were actually mesospheric clouds, the following conclusions can be drawn as a result of the observations which were carried out:

1) mesospheric clouds are easily visible from outer space against the background of the twilight segment;

2) when mesospheric clouds are observed from a spacecraft's orbit their spatial structure is visible, and its form very significantly in proportion to the motion of the spacecraft;

3) when mesospheric clouds are observed from outer space, they have details of a somewhat different type than when they are observed by ground-based stations.

In conclusion of this communication, we should note that the observations of mesospheric clouds from outer space will undoubtedly permit solving a number of scientific problems with an incomparably higher accuracy than observations from ground-based stations.

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